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L. W. P.

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BEAN DISEASES AND THEIR REMEDIES

B. D. Halsted.

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NEW JERSEY
AGRICULTURAL EXPERIMENT STATIONS
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JUNE 1, 1901

Bean Diseases and Their Remedies.

BY BYRON D. HALSTED.

The numerous species belonging to the group of true beans, taken as a whole and the wide world around, have many fungous enemies. In the present paper only those diseases are considered which have so asserted themselves as to become troublesome to the growers of the ordinary garden sorts. This will include the varieties of the common or kidney bean (*Phaseolus vulgaris L.*), and the Lima bean (*Phaseolus lunatus L.*), with possible mention of closely related species, some of which are grown for ornament.

It is several years since the diseases of beans were made a subject of study at this Station* and they have been almost constantly under observation during the past decade. In the spring of 1894 field experiments with diseases of truck crops were begun and beans have ever since received a full share of attention. One plot of ground, one twentieth of an acre, has, for example, been in beans, two crops each season, for the past seven years, while other equal areas have been carrying the same crop for shorter periods of time.

While it is true that these diseases may flourish at the same time, and upon the same plant, and in the experiments they have necessarily been considered in their association with one another, it is best for the present purpose that each be described by itself. To this end several photo-engravings are given, that, in connection with the descriptions will, it is hoped, enable the crop-grower to determine which of the leading bean diseases is doing injury to his plants.

*The Anthracnose of the Bean—Remedy Suggested, Annual Report N. J. Exper. Sta., 1891, pages 284-287.

THE BEAN ANTHRACNOSE.

Usually the most destructive disease of ordinary beans is the Anthracnose. This is due to a fungus that was first observed by Lindemuth at Popplesdorf, near Bonn, in August, 1878, and soon after named in his honor.*

The common name of "Bean Pod-Spot" has been given to this disease, because it is more conspicuous upon the fruit than any other portion of the plant. This anthracnose causes the pods, often while they are quite young, to become specked with brown, which spots afterwards develop into sunken ulcers and ruin the pods. Figure *a*, Plate I., shows four pods of the common bush wax beans badly infested with the anthracnose. The pods upon the right give the young stages of the disease, but as the spots enlarge and their areas blend the appearance shown by the pods upon the left hand results and the fruits become worthless. The disease spreads rapidly from pod to pod (as for example, in the market place), as has been shown by repeated inoculations in the laboratory, where, under the most favorable conditions, a spot may be established upon an otherwise healthy plant or pod in thirty-six hours. The infection is from without and may be by means of the winds, dripping water bearing the spores, or through the agency of insects, which visit the bean flowers for their honey and incidentally convey the germs with the flower dust (pollen) they are distributing among the blossoms. This method of infection by means of bees will be considered more in detail later, in connection with the mildew of Lima beans.

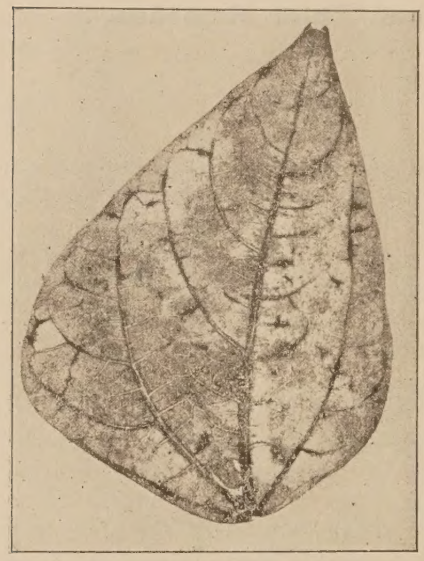

Fig. 1.
Bean Leaflet, with Anthracnose.

* *Gloeosporium Lindemuthianum* Sacc. & Magnus Michelia I., page 129, 1878. In 1893 it was placed in *Colletotrichum lagenarium* (Pass.) Bul. Torr. Club.

The plants that bear the diseased pods usually have the foliage more or less affected ; but it is not conspicuous excepting in bad instances. The anthracnose upon the leaves can be best detected by inspecting the underside where the disease develops, particularly along the midrib and main veins, causing a more or less reddish discoloration. The general appearance of a badly anthracnosed leaflet is shown in Figure 1.

Fig. 2. Anthracnose Bean, seedling and seeds

Seed Infection.

At the outset the point of special interest to practical bean-growers is the well demonstrated fact that the disease is carried over the winter in affected seeds, which, if planted, may produce sickly seedlings that have their young stem and other parts spotted in the same manner as the diseased pods previously mentioned. Three such seedlings that have been ruined by the anthracnose are shown at *b* in Plate I. The photograph was unfortunate in not showing the spots clearly, but the lack of any healthy leaves and the general collapse of the young bean plants are at least apparent. The pen-and-ink drawing, given as Figure 2, may help to show the appearance of an affected seedling, as seen at *a*, while a diseased bean is given whole at *b*, and as split through the middle of *c*. The darker portion in all cases is the affected area. By leaving diseased beans in a moist place, with sufficient warmth, a rank growth of the anthracnose is quickly developed upon the brown portions and rapidly spreads over the healthy parts of the seed.

The spores germinate quickly, and in forty-eight hours produce threads of considerable length. They may be studied in their growth upon artificial media, as has been done by Prof. Atkinson.*

Treatment of the Seed.

It has been demonstrated that when anthracnosed seeds are planted the diseased seedlings from them become centers of infection and the whole stand of bean plants may be ruined. The treatment of the seed was naturally one of the first matter for experimentation, and

* "Some Observations on the Development of *Colletotrichum lindemuthianum* in Artificial Cultures." Botanical Gazette, Vol. 20, pages 305–311, with plate of photo-micrographs of the bean anthracnose spores and germ hyphæ.

in 1891 this line of investigation was taken up. It can be stated that with Bordeaux, in various strengths, no good results were obtained. Other experimentors have worked along similar lines with varying results.

Professor Beach* soaked beans in water at 140° F. for five minutes, 130° F. for fifteen minutes, in Bordeaux, in cupram, copper sulphide, corrosive sublimate and in potassium sulphide for one hour, respectively, and the hot water gave the best results, but they were not satisfactory.

Professor J. Craig† has soaked beans in cupram and potassium sulphide and demonstrated that the anthracnose can be checked. The best results were secured by soaking for one hour and while the percentage of germination is somewhat lowered by the treatment, the quality of the crop was much improved.

The subject has received attention in other countries, thus E. Gain‡ reports that anthracnosed seeds are less dense than sound ones, the difference amounting with one variety to form 3.4 to 4.8 per cent. and in others as much as 8 per cent. The germinative ability of diseased seed was also studied, and it was found in a series of experiments that 10 per cent. of the seeds did not germinate, while only 46 per cent. made viable plants, the sound seed producing 98 per cent. Experiments were conducted in the laboratory and in the field to test the propagation of the disease by seed and other means, and it was found that it spreads quite easily from diseased seed. The conclusions, briefly summarized, show that diseased seeds are easily recognized by their lessened specific gravity and lower germinating power. Plants from diseased seed are less resistant to subsequent attacks and seldom develop equal to those from sound seed. The distribution of the disease is easily effected through the soil or seed. The author recommends that seed be carefully hand-selected before planting and the lighter seed thrown out.

No treatment for the seed, like soaking in chemical or heated water, can be recommended. While such methods are very effective with cereal grains having smut spores clinging to the surface, the case is quite different with the large smooth bean seeds, which carry the disease internally, and when placed in liquids their skins are quickly wrinkled and break open. A method of seed treatment may yet be devised to destroy the anthracnose and not harm the seed ; but for

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*N. Y. Sta. Exper. Sta , Bull. 48, Dec., 1892, pages 308–333.

†Canada Exper. Farms, Rept. 1892, pages 97–108.

‡Compt. Rend. Acad. Sci., Paris, 127 (1898), No. 3, pages 200-204, E. S. R.

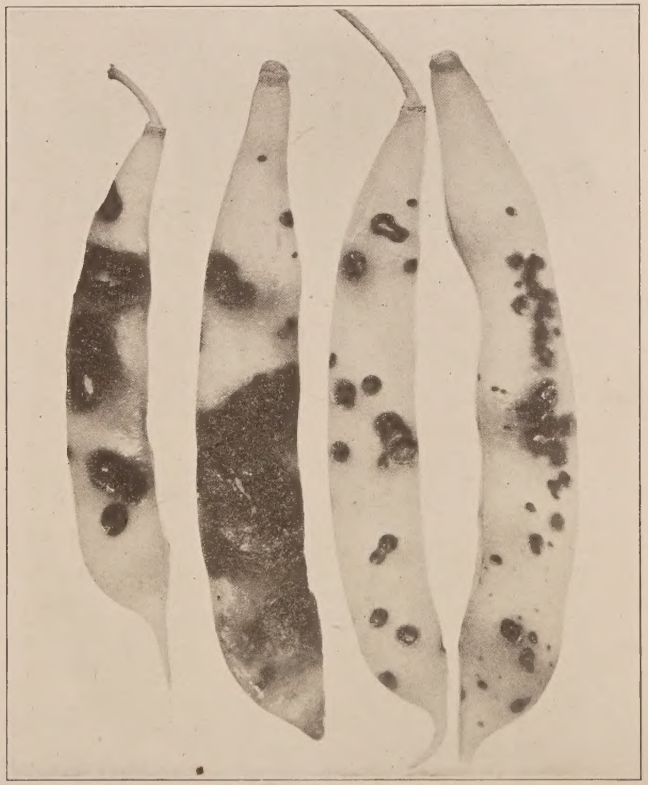
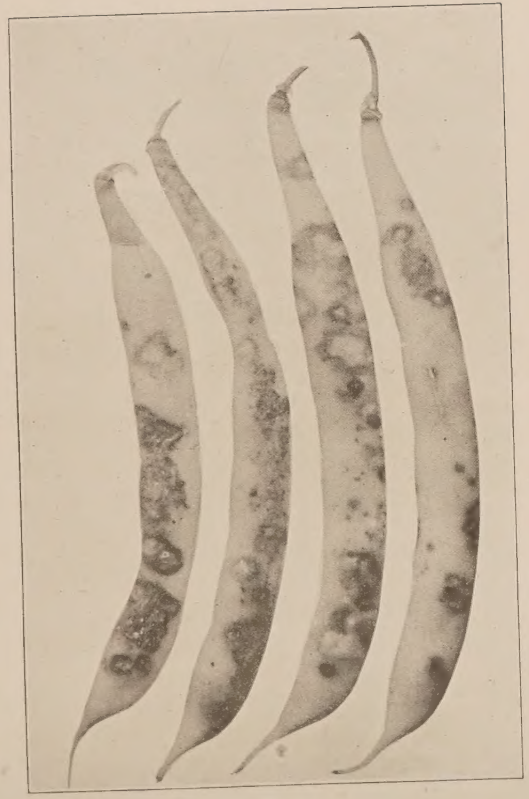


PLATE I.

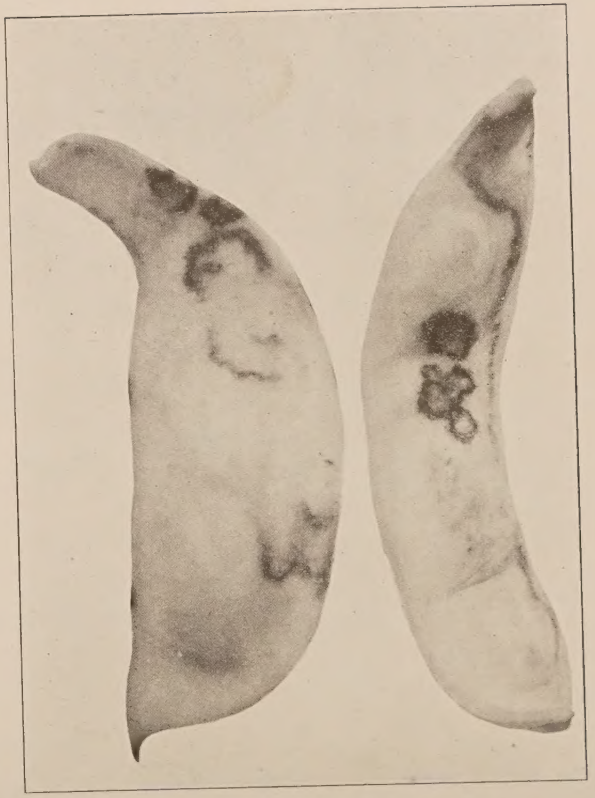
A. Four Anthracnosed Bean Pods.

B. Three Anthracnosed Bean Seedlings.



A. Four Bean Pods with Bacteriosis.

PLATE II.



B. Two Lima Bean Pods with Bacteriosis.

the present the only precaution that can be urged is that of a thorough inspection of the seeds and the exclusion of those not appearing perfectly sound.

Spraying the Plants.

The treatment of the plants, while growing, was begun in 1894, and spraying in one way or another has been tested during all the subsequent years.

A. Bordeaux Mixture.—The formula for this standard fungicide has varied somewhat from year to year; during the first season it was employed in three strengths, namely, the five pounds of copper sulphate and five of lime and twenty-five of water, as the so-called "full-strength," and double the water for the "half-strength," and four times as much for the "quarter strength." In later years less lime has been employed, and for the last three seasons the standard strength has been "6–4–60," that is, copper sulphate, 6 pounds; lime, 4 pounds, and water, 60 gallons.

The record of the results for the first year shows that while the Bordeaux was effective in checking the disease, the "half-strength" was as good as the "full-strength." In 1895 the "full-strength" Bordeaux was found to dwarf the plants somewhat, while a weaker solution did not. In 1896 the Bordeaux was used as a standard with which to compare other fungicides, and it may be said, once for all, that the various substances used to prevent the diseases are measured in effectiveness by that of the Bordeaux mixture. In this year, while there was an abundance of the anthracnose, it was confined almost wholly to the unsprayed belts. The year 1897 was noted as one in which plant diseases were not abundant, and for the anthracnose no results were obtained for Bordeaux, and the same is true of 1898, for as stated elsewhere, "the disease present was entirely of the bacterial sort."

During last season, for the first crop, Bordeaux was used upon the soil in the open row at time of planting, and here the number of diseased pods was smaller than in the check. Certain portions of the plot were sprayed early only, while others received the late applications only, and there was a small gain in favor of the early sprayings.

B. Soda-Bordeaux.—This fungicide was first placed on trial in 1895 and has been kept on the list ever since. For the first year, under the name of "Hydrate," the record for beans is "nearly as free from blights as * * * with Bordeaux." As employed for the last two years the formula is :

Copper sulphate	3 pounds.
Soda (lye)	1 pound (a can).
Lime	5 ounces.
Water	30 gallons.

The small amount of lime is to insure the mixture from turning brown, but the fungicide is nevertheless a comparatively clear liquid, and for that reason is desirable when the thick lime coating of ordinary Bordeaux is objectionable. With bush beans, after extensive and extended trials, the soda-Bordeaux has proved as effective as the standard Bordeaux along side of which it has been tested. The

Fig. 3.
Bean Anthracnose Inoculated upon Citron.

small amount of anthracnose in 1898 and 1899 has been the only thing standing in the way of a complete trial of the mixture.

C. Cupram.—This is the short name for the ammonical carbonate of copper mixture and one of the leading fungicides. It was employed for two crops in four different strengths, the full-strength formula proving the best and quite effective against the anthracnose. Its value is established and was set aside to give room for testing other mixtures, the Bordeaux only being retained as a measure of effectiveness.

D. Potash-Bordeaux.—This is the same in construction as the soda-Bordeaux in which the soda is replaced by potash. The difficulty of bringing the potash into solution is an objection, as it is a refractory solid. The so-called "granular potash," as it comes in small cans for domestic use, turns out to be soda, and the genuine potash for the experiments was obtained in ten-pound cans. When potash is used as a spray and reaches the soil, it becomes an available plant-food, after having served as a fungicide. With the beans this mixture shows in the record that "the percentage of spotted pods * * * was lower than in either of the other two sprayed belts adjoining."

A number of other substances have been tested, as potassium sulphide, Eau Celeste and creolin, which last proved practically worthless.

Professor Craig* reports as follows upon the subject in hand: "Experiments were conducted with corrosive sublimate, kainit, nitrate of soda, potassium sulphide, formalin, and lysol for the prevention of bean anthracnose. One and one-half per cent. solutions of lysol gave satisfactory results, followed by formalin and potassium sulphide. If further trials of these fungicides should corroborate the results given, lysol would supersede copper sulphate as a preventive of bean anthracnose, as the results obtained are more satisfactory than those in former experiments with copper sulphate."

Professor Rolfs† gives suggestions for preventing bean anthracnose through spraying with Bordeaux, and recommends a clear fungicide as eau celeste, when pods are nearing marketable size.

Professor Harvey‡ states that the bean anthracnose is quite common upon both bush and pole sorts. He recommends selecting good seed, destroying all affected seedlings, spraying early with Bordeaux, planting upon ground new to beans and dry soil in hills.

Mulching with Spotted Pods.

The spotted pods from four belts from the first crop were applied to the surface of one belt when the beans of the second crop were two weeks above ground. The following is the table of results:

	Weight of plants.	Good pods.	Spotted pods.
Mulched	20.5 pounds.	18.5 pounds.	64 ounces.
Not mulched	26.75 "	18	21.5 "

* Canada Exper. Farms, Rept. 1897, pages 110-120.

† Florida Sta. Rept. 1896, page 48, Fig. 2.

‡ Maine Sta. Rept. 1893, page 152.

This shows that there were more than three times as many spotted pods upon the mulched land as the check. The leaves upon the bean plants of the mulched belt were nearly all more or less diseased.

The effect of the mulching seemed to last over into the next year.

Distance Apart in the Row.

Several tests have been made of the distances between the plants in the row, as likewise the width of the spaces between the rows. As a rule, however, unless otherwise stated, the latter distance of rows is 20 inches, and in the row 6 inches. In the second crop of 1894 one belt was used for the test of distances, with 3, 6, 12 and 24 inches under consideration, with the result that the yield of the plants, 3 inches apart, was double that of the 6, and four times that where the distance was 12 inches. In 1895 considerable attention was given to the matter of distance in the row, and $4\frac{1}{2}$ inches, 9 inches and 18 inches were the chief ones under consideration. The $4\frac{1}{2}$-inch distance was to the 9 and 18 as 106 to 72 and to 61 respectively. In a trial with a second crop of the same year, the distances were 3, 6 and 12 inches, and the results were in weight of product as $16\frac{1}{3}$, 12 and $6\frac{1}{2}$ respectively. These experiments indicated that no distance is superior to 6 inches in the row for bush beans of the golden wax sorts when the rows are 20 inches apart, but it should be stated that less space is required in the second than in the first planting of any season.*

A point of special interest in this study of the distances was the smaller amount of anthracnose upon the plants that were widely separated. To quote from the record of 1895 : "The indications of these tests of distances, so far as the pod spot is concerned, are that the more crowded the plants the greater the opportunity for the disease to develop."

It has been found that the diseases vary greatly with the seasons. In 1894 the anthracnose was quite abundant upon both spring and autumn crops. In 1895, in the second crop, and the fourth in succession upon the land, the percentage of spotted pods was 21.7. This crop was left until it was well advanced and harvested and photographed in piles.† In both crops of 1896 there was practically no anthracnose (three pods) in the three sprayed belts, but abundant

* "Seven Years of Experiments with Bush Beans," by the writer.—Soc. Pro. Agr'l Sci., 1900.

† Engravings showing the results were published in the annual report for 1895, pages 283–293.

where no spraying was employed and twice as abundant upon the irrigated belts as the checks.

In 1897, for the first crop, the report reads, "almost no blight appeared anywhere," and the same is true of the second crop.

In 1898, for the first crop, the record is, "the disease present was entirely of the bacterial sort," and for the second crop the anthracnose was very slight. Last season there was still less, and the anthracnose had practically disappeared.

One is almost called upon to wonder why this decrease of the anthracnose has gone on through the several years.

Bean Anthracnose Upon Melons.

The range of the hosts of the bean anthracnose is a point of economic importance, as well as of scientific interest. It is found that it thrives upon the melon tribe as well as the beans. In order to demonstrate this point, in 1892 the writer* made reciprocal inoculations between the bean and watermelon. A third kind of fruit not usually affected, namely, the citron, was employed, using specimens small enough to go under a belljar. The virus was taken from the bean and applied to the citron at a few points upon one side of an ink line drawn lengthwise of the fruit, while similar inoculations were made from a watermelon upon the other side. Both grew with equal rapidity and shortly the two groups blended in a common decayed patch. The general appearance of the inoculated citron is shown in Figure 3. To the practical grower there may be in this, a reply to the question, sometimes raised whether melons are more apt to contract anthracnose after beans than other crops or contrariwise. It goes without saying that in the light of facts it is not wise to follow a blighted crop of beans or melons with melons or beans respectively. To the student of science it is of interest that plants so widely different as those mentioned should have the same disease.

BACTERIOSIS OF BEAN.

There is a bacterial disease of the bean that is particularly destructive upon some varieties, and infests both the Lima and the ordinary sorts. This trouble was first brought to notice by Professor Beach† who found it abundant and wrote concerning it. "It developed into a serious malady about the first of August, and did the most damage during the hot weather of that month. A plot of wax beans was the

*Identity of Anthracnose of the Bean and Watermelon, Bull Torr. Bot. Club, June, 1893.

†Bull. 48, New York Agricultural Exper. Sta., Dec., 1892.

first to be badly affected, and the plants were ruined within a few days after the serious nature of the disease first attracted attention."

It appears upon the foliage, stems and the pods, and is easily distinguished from any other trouble of beans. Upon the foliage, usually the first parts to be attacked, it produces large, watery brown patches that shortly become dry, and the tissue curls and breaks away, leaving the foliage ragged and worthless. Figure 4 shows the

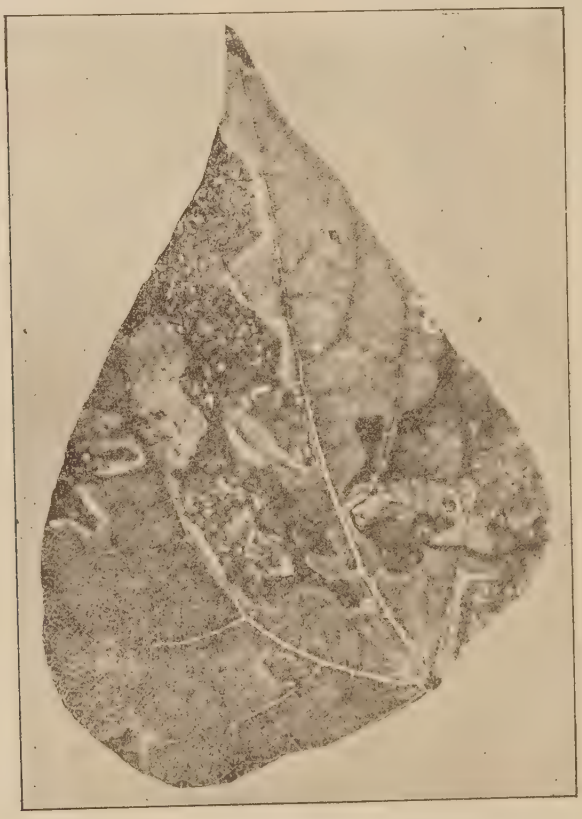


Fig. 4.
Bean Leaflet, Showing Bacteriosis.

general appearance of a leaflet in the early stages of this destructive disease of the bean.

The pods are a favorite part for the bacteriosis, where it first shows itself as small "water-logged," discolored spots that spread rapidly and produce large patches, with borders tinged with a pink and

bearing a pale, amber-colored incrustation upon the most affected part. This amber color is due to the vast numbers of the bacteria that have formed into a layer over the ulcerous tissue of the diseased spots. A little later the pod becomes rotten and the fruit is worthless. Plate II. (*a*) shows four pods in the various stages of the bacteriosis. The photograph was made from diseased pods preserved in alcohol, and the coating of germs is not present. The difference in appearance between the bacteriosis and the anthracnose is much greater than the engravings would indicate, because of the lack of the natural discoloration in them, and the fact that the camera is unable to preserve many details easily shown to the eye by the specimens themselves. Often the same pod will bear both of the above-named diseases, and when side by side they are easily distinguished. However, to the practical grower it is not so much the appearance as the remedy that is of greatest interest. It may be said here that the two diseases are in common, to a large extent, and all that has been stated concerning the anthracnose and its being perpetuated and spread through the seed holds good with the bacteriosis, and in fact the two diseases may, for all practical puposes, be considered as one, so far as the seed is concerned. It only needs to be added here that extreme care should be taken to reject all imperfect seeds, namely, to repeat, those that are immature, discolored, light in weight, etc., should be carefully discarded.

The disease under consideration is due to a micro-organism that has been especially studied by an expert of germ diseases of plants, Dr. E. F. Smith, who has given a description of it* as consisting of "a short rod with rounded ends, yellow on various media, motile in early stages of growth, decidedly pathogenic to beans and some related legumes. It is closely related to the bacteriosis of the hyacinth and of the cabbage." Figure 5 shows three of the organisms, one thousand times magnified, taken from Professor Smith's plate.† It is seen that there is one long slender flagellum to each bacterium. This species bears the botanical name *Pseudomonas phaseoli* Sm.

Fig. 5.
Magnified View of Organisms Causing Bean Bacteriosis. (After Smith.)

Remedial Measures.

The number of the bacterial diseases of plants is not small, the fire-blight being one of the most destructive, while another species

* Proc. Am. Assn. Adv. Sci., Vol. XLVI., page 288, 1898.

† Wakker's Hyacinth Germ. Bull. 26, U. S. Dept. of Agric., Div. Veg. Phys. and Path, 1901, Fig. 11, Pl. I.

destroys growing sweet corn and another carrot roots, while a very serious one is active upon tomatoes and potatoes. Mention is made of these to show the general nature of the bean bacteriosis. It is determined that the germs of some of these species of micro-organisms are carried by insects. For example, Dr. Smith has demonstrated that the germs of the tomato bacteriosis are carried by Colorado beetles from one potato plant to another, and the time of incubation is seven to nine days. It is not unlikely that any insect feeding upon the bean will serve to spread the bacteriosis under consideration, and it therefore follows that any measure that tends to check the bean insects will do the same for the bacterial disease, should it be present.

All that has been said concerning spraying under anthracnose, page 7, applies to the bacteriosis, but it must be borne in mind that the anthracnose has decreased and the bacteriosis increased during the seven years of the experiments, and therefore the results for the first three seasons are more with the anthracnose in evidence and the last four when the bacteriosis was more prevalent. It follows that while Bordeaux has been used through all years, cupram was only employed in 1894, and the soda-Bordeaux for the last four seasons, when the bacteriosis was the chief disease. So far as results could be obtained there is no indication that any fungicide good for controlling the bacteriosis will not be equally effective with the anthracnose, which is an easy enemy to subdue.

From observations that the writer has made upon the bacteriosis, it seems evident that the disease is greatly favored by surrounding climatic conditions. This seems to hold true with all fungous diseases, and therefore no matter what precautions are taken the disease may be much more abundant some seasons than others. This fact should not tend to discourage the grower, but contrariwise make him all the more vigilant, so that only the unpreventable conditions will work against him. The following observations upon the disease in hand may enforce the importance of small details upon the outcome of a crop :

In the bean plots the rows run nearly north and south, and in 1897 (autumn crop), upon the east side of the plants, there was but a small amount of the bacteriosis to be seen, while upon the west side nearly every pod of the "green flageolet" variety was more or less blotched, some of them literally covered with the bacterial ulcers, which were in many instances of an amber color, due to the multitude of the germs of the bacillus that had collected in a layer

upon the surface. Fully nine-tenths of all the blotches were upon the western sides of the pods, and about two-fifths of all the pods of the variety in question were badly affected.

Strong winds upon the 17th and 20th of September bent the plants to the southeast, from which they did not fully recover. As a result, at the time the above observations were made, October 15th, the plants all leaned several degrees from the perpendicular, and some of the pods were likewise tilted. In short, the foliage of the plants hung chiefly upon the eastern side of the row, and had done so for between two and three weeks, and therefore one side of each pod was more exposed than the other, and that exposure was, speaking generally, in the direction of the four o'clock sun.

It had been previously observed that the leaves of the plants under consideration were badly blighted for weeks before the pods became noticeably injured, and it is not unlikely that the germs were carried from the diseased leaves to the pods by the dripping dews, in which case the side that was slightly inclined upward on account of the slanting posture of the plants would receive a more generous supply of the germs than the more protected underside.

It is possible that the bending of the plants so exposed the pods that they became more or less injured by the sun, and thus provided more favorable conditions for the development of the bacteria. The warmth of the sunny side may have been sufficient to make the difference observed.

All the circumstances may have combined to bring about the results that were so strikingly evident. The bending of the plants and the swinging of the foliage to the eastward, the inclining of the pods and the exposing of the upper surface, that would naturally receive the drips from the diseased leaves, the autumn sun during the afternoon, either adding the required warmth for the germs or partially scalding the side most exposed, and thus render the tissues more susceptible to attack, are all still unsettled points in this connection. One cannot but wonder what the result might have been had the plants been pressed back into place after the storm, or a portion of the plot had been shaded, or even if the rows had run east and west instead of north and south.

Some Results with Anthracnose and Bacteriosis.

A number of experiments were made upon the bean plots, the results of which apply to both the two preceding diseases, and are here considered together to save space.

Irrigation.—The test of irrigation for 1895 was one belt of fall crop from September 17th until October 9th, ten applications being

made between the rows, the water flowing down channels and soaking into the soil, about 150 gallons being applied at each time, and making a total of about 1,800 gallons for the belt of 11 by 33 feet. This, in terms of rainfall, is about eight inches, or nearly double the average normal precipitation for the period covered by the irrigation.

It is recorded that for irrigation there was a large increase of spotted pods. In this instance the water was all applied to the soil and none fell upon the foliage. The pods, however, were doubtless in a better condition to receive and develop the disease, which in this case, was largely the bacterial sort, the anthracnose or pod-spot forming but a small percentage of the trouble. This experiment shows that irrigation may double the yield of pods, but at the same time the diseases may be increased in a still greater ratio.

In 1896, more extensive tests with irrigation were made, and began with the first crop upon May 8th and continued until July 4th, with fifteen applications. The rainfall during the time covered by the trial was only a trifle below the normal and the irrigation was not needed and proved a hindrance. The record shows that there was "an increased amount, nearly double, of anthracnose over the check-belt and somewhat less of the bacterial blight."

Shading.—Along with several other truck crops shading was tested with the bush beans. The shading was effected by placing frames of lath upon stakes being held in position by stout strings. Each lath-frame was four feet square, and made by nailing ordinary carpenter's laths to laths at their ends, with a single lath interwoven across through the middle. The vacant space between the laths was equal to the width of the lath, so that the actual amount of shading was half that of total and may be spoken of as half-shading. Sixteen two-inch stakes were driven into the ground so that each of the nine frames would rest upon stakes at all four corners. The height at which the shading was placed above the soil was about two feet.

The weight of the whole crop of vines and pods was somewhat greater for the plant in the full sun than in the shade. There were five times as many ripe as green pods upon the sun-exposed plants, while with the shade the green pods were very much more numerous. It is gathered from the test that the half-shading is not disadvantageous for the spring crop, for the period when pods are suitable for the table is materially prolonged. For the second crop the shade has the effect as before of somewhat retarding the time of blooming, but it kept the plants from injury by early frost, they remaining in full leaf when the fully-exposed plants had only bare stems. The primary object of the shading in this case of beans, namely, a study

of its influence upon the development of fungi was thwarted by the diseases not appearing in abundance anywhere in the plot.

Sprinkling.—The plants in the one belt in 1898 were sprinkled with water twice daily at 10 A. M. and 2 P. M., from August 30th to October 1st, rainy days and Sundays excepted, and this treatment had no appreciable effect upon the foliage or pods, and in common with other plants of the bean area remained practically free from all disease.

Old and New Land.—After the first season (1894), the beans in the plot under consideration were planted in comparison each year with a plot in all other points the same excepting the fact that it was where beans had not been previously grown.

In 1895 the yield was 733.25 pounds of pods upon the old ground, and 645.75 pounds upon the new land; with the spotted pods, 197.25 pounds upon the old and only 40.25 pounds upon the new land, or nearly five times as much upon the old as the new ground. In the second crop, upon the same plots, the difference was also in favor of the old land for yield and against it for diseased pods.

In 1896 the results for both crops were nearly the same as for the previous year, both as regards the anthracnose and bacteriosis.

In 1897 the average yield for the first crop per belt for the old land was 22.5 pounds to 17.9 pounds for the new land. For the second crop there is less difference.

In 1898 it was observed that the plants upon the old land (this being the ninth crop) grew more vigorously from the start than those upon the new land, but in actual yield of pods the new land was slightly in excess of the old soil.

Last season, for the first crop, a comparison of the untreated belts with those upon the new land, shows that there was some small gain for the new land in total yield, but with the diseased pods twice as many upon the new as the old soil.

The disease was almost entirely bacteriosis, and the cause for the outbreak upon the new land is not easily explained.

Mulching.—In 1896 three mulches were employed for the purpose of comparing their merits from a mechanical standpoint, and further to determine whether the plants mulched with one sort of material were notably superior or inferior to those mulched with another. Fresh hay, marsh or salt hay, and "excelsior," were used as mulches. The fresh hay, in comparison with "excelsior," did not give evidence of acting as a fertilizer, and there was no great difference in the behavior of the three kinds of mulch. The mulched rows in the first crop of beans gave a somewhat larger yield, but there was no prac-

tical difference in the amount of blight and pod diseases. In the second crop there was no difference between the mulched and unmulched plants, and the conclusion suggested by the tests was that mulching of beans is only of value when the season is with less than normal rainfall.

Ridging the Land.—In the late autumn of 1898 one-third of the land in each plot was thrown up into ridges, so that the crests were about two feet above the valleys, the thought being to expose it more fully to the action of the elements. The ground was brought to a level in the spring, and the beans planted here and upon the adjoining land that had been ridged. It was found that this winter treatment did not influence the yield and had no apparent effect upon the diseases.

Variety Testing.—Something has been done in testing varieties, chiefly with reference to susceptibility to the diseases. During the first season only one sort, the "Improved Golden Wax," was employed, and no change was made until 1897, when six varieties were grown in as many parallel rows in each belt, namely, (1) Green Flageolet, (2) Currie's Rust-proof, (3) Early Mohawk, (4) Golden Wax, (5) Extra Early Refugee, (6) Saddleback Wax.

In productiveness the varieties were from greatest to least, as follows: (1) Early Mohawk, (2) Green Flageolet, (3) Saddleback Wax, (4) Currie's Rust-proof, (5) Early Refugee, (6) Golden Wax. Practically the same order was maintained for both old and new land. There were great differences in the amount of disease, the Green Flageolet being most susceptible and the Early Refugee the least.

In 1898 the number of sorts was reduced to four by omitting Early Mohawk and Currie's Rust-proof; upon both the old and new ground the relative yields were the same, the Early Refugee leading, followed by Golden Wax, Saddleback Wax and Green Flageolet, in the order named. In diseased pods the Green Flageolet was first, while Saddleback Wax, Golden Wax and Early Refugee were practically the same and least susceptible.

In 1899 only two varieties were grown, namely, Green Flageolet and Saddleback Wax, and the former maintained its record for small yield and large percentage of disease.

THE DOWNY MILDEW OF LIMA BEANS.

The most serious disease of the Lima beans is the mildew. This fungus (*Phytophthora Phaseoli*) was first described by Dr. Thaxter* and later more fully† considered by him with engravings, some of

* Botanical Gazette, Vol 14, page 273, Nov., 1889.

† Conn. Agr. Exper. Rept., 13, 1889, pages 167–170.

which are herewith reproduced through the courtesy of the Connecticut Experiment Station. While the fungus is very easily seen in itself and also indirectly prominent from the destruction it produces upon the affected Lima bean plants, its native home is somewhat of a puzzle as evidenced by the following lines written by its discoverer: "Its origin * * * is purely a matter of conjecture since, although it seems scarcely probable that so conspicuous a form should have been overlooked in so thoroughly explored a region as the New England and adjacent States, it has been equally overlooked in other parts of the world, if indeed it is a foreign importation."

Fig. 6.
Two Badly Mildewed Lima Bean Pods.

It was not long before this mildew was met with in other States, and at the present time it is a serious menace to the growers of Lima beans in New Jersey. The records show, for example, that the disease has been abundant in Bergen county. "Here the pole Limas were so badly attacked that few or no pods were picked from some of the fields. The mildew was worse with plants growing upon rich lowlands and where the same crop had been upon the ground the previous year."* Not only the young pods, but

* Rept. N. J. Exper. Sta., 1897, page 297.

the whole flower clusters were destroyed and the dead tips of these stood up above the surrounding leaves of the affected plants. The general appearance of the mildewed pods is shown in Figure 6, the engraving having been made from a photograph of two diseased pods, while the ruined flower clusters are similarly shown below in Figure 7.

Fig. 7.
Tips of three Bean Plants Ruined by Mildew.

A microscopic examination of the affected part of the plant shows that it is penetrated by the slender threads of the fungus, which come to the surface and there produce tufts of branching filaments and bear multitudes of spores, all of which constitute the light mouldy covering, and suggests the common name of downy mildew

that is given to many members of this family. For example, there is a closely-related mildew of the grape, another of indoor lettuce, another of onions, while the potato-rot fungus, often extremely destructive, is very near of kin to the bean Phytophthora. Figure 8 gives some of the microscopic details of the mildew. At *a* is shown a portion of the diseased bean pod with the threads passing through the stoma and bearing the spores upon their tips. A more enlarged view of the mildew is shown at *b*. The enemy in question belongs to a group of fungi, the members of which are among the most fatal of all that afflict crop plants and therefore demand prompt attention upon the part of the grower when met with.

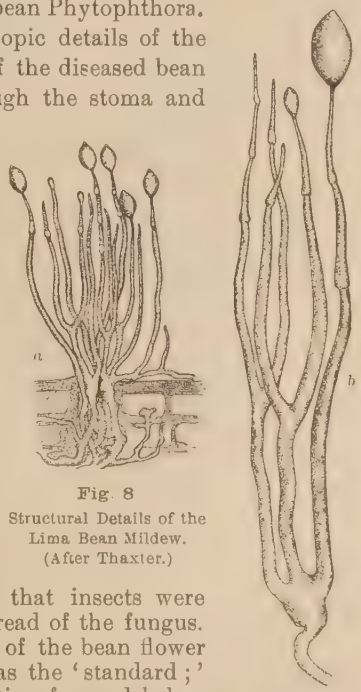


Fig. 8
Structural Details of the Lima Bean Mildew. (After Thaxter.)

Dr. W. C. Sturgis has made a careful study of the Lima bean mildew, and is impressed with the important part that insects play in the spread of the disease. He writes :*

"The occurrence of the mildew on the pods at a very early stage of their growth led to the supposition that insects were responsible in a measure for the spread of the fungus. * * * The conspicuous portions of the bean flower consist of an upright petal, known as the 'standard;' two narrower petals distinct, projecting forward below the standard, and known as the 'wings;' and two petals united in the form of a closed, spirally-coiled tube, occupying a position between the standard and the wings and called the 'keel.' (Figure 9.) At the base of the keel is the ovary of young pod surrounded by the stamens and prolonged upwards into the style. The long stamens and style are completely enclosed in and protected by the keel.

"Under such conditions cross-fertilization would seem to be impossible, especially as the pollen is shed abundantly from the anthers which are borne upon the stamens in close proximity to the upper portion of the style, and neither the stigma nor the anthers appear beyond the end of the tube in which they are enclosed. But the wings form a convenient resting place for visiting bees in search of nectar, and in case a bee lights upon them his weight deflects them and at the same time draws the keel down and backward, thus causing the stigma and the hairy portion of the style covered with pollen

* Report Conn. Exper. Sta., 1897, pages 159, 160.

to protrude from the mouth of the tube. (Figure 9.) As the insect plunges his head into the flower, the stigma and pollen-laden style comes into contact with his abdomen and cross-fertilization is assured by subsequent visits to other flowers. But fungus infection is assured with hardly less certainty, provided the bee has previously had contact with the spores of the fungus. In that case we should expect to find the first attack of the fungus at the two points where the bee, in his search for nectar, touched the more moist and delicate tissues of the flower, viz., on the style and at the base of the ovary or pod.

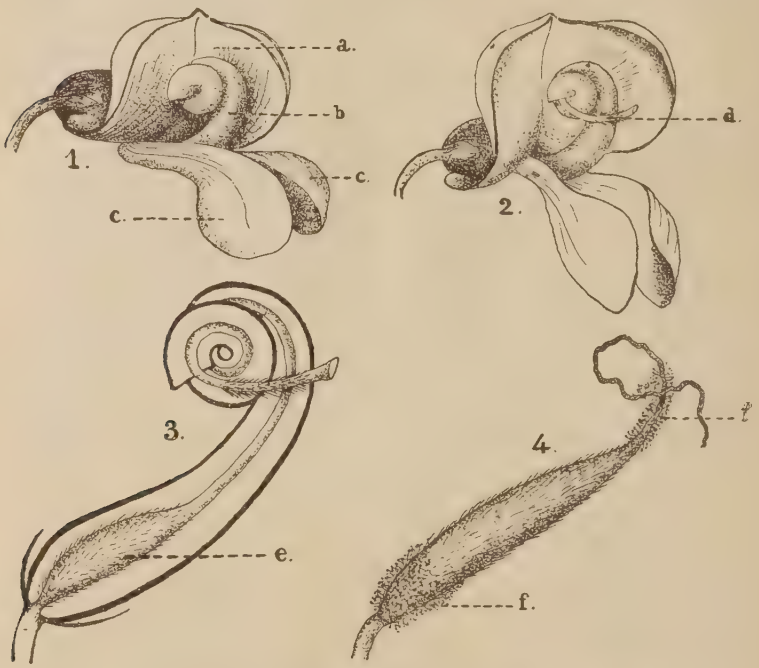


Fig. 9.

Bean Blossom; (1) *a*, Standard; *b* Keel; *c* Wing Petals; (2) Wings Depressed and Style Protruding; (3) Same Enlarged with Ovary at *e;* (4) Young, Shriveling Pods, Showing Mildew at *f f*. (After Gray and Sturgis).

"A large number of flowers was examined, and this supposition was strikingly confirmed. The mildew was found in many of the flowers, and in every case it occurred on the spots above mentioned and nowhere else. (Figure 9.) It seems certain, therefore, that the spread of this mildew is largely due to the agency of insects, particularly of bees, and this view is further confirmed by the fact that in the case of young pods the mildew almost always appears first at the base or tip, and very rarely in the middle.

"That the wind also plays an important part in the dissemination

A. Four Lima Bean Pods Showing Blight.

PLATE III.

B. Three Lima Bean Leaflets Showing Blight.

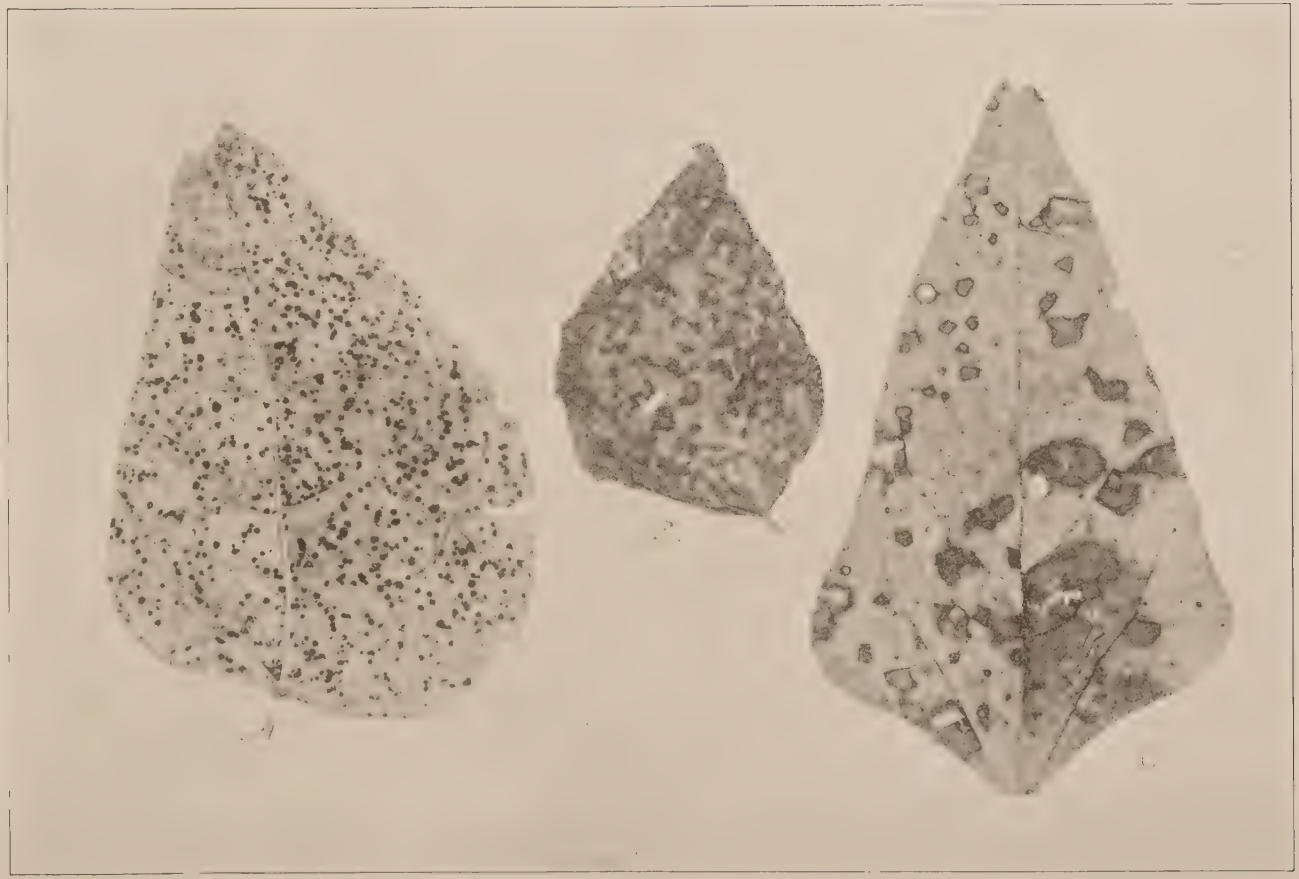


PLATE IV.

of this mildew, seems certain. When the vines are seriously mildewed the fungus frequently appears first, not at either extremity, but upon one side of an almost mature pod, and generally on the side farthest from the vine and least protected by leaves. Thaxter has also noted its occurrence on the leaves. Neither of the cases can be due to infection on the part of insects, and we must conclude that the spores may be carried by the wind, or that water falling upon and dripping from infected portions may carry the spores down to sound pods hanging beneath. That mature uninjured pods can be infected with the fungus and that the wind can disseminate it, is indicated by the following facts :

"The Lima beans on the Station grounds are on high land, composed of a light, sandy soil, and have never been affected with mildew. The rows run east and west. Directly south of them, at a distance of about one hundred feet, but separated from them by a pile of lumber and a few trees, are two rows of bush Limas running north and south. On August 14th, when the mildew had been abundant in the neighborhood, the Station vines were examined and found to be entirely free from the fungus. A few mildewed pods were brought from a distance, and the spores from one of them were rubbed and dusted on the surface of a sound and nearly ripe pod at the east end of each row of the pole Limas. Within a few days the mildew made its appearance on the infected pods, and from this point of vantage, the prevailing winds at the time being from the northeast and north, it swept down both rows and in two weeks the whole patch was completely mildewed. The spores had also been carried over a distance of one hundred feet to the bush Limas, and the mildew, beginning at the north end of the rows, that is, at the point nearest to the pole beans, spread rapidly down the rows. It is evident, then, that spores placed upon the surface of a sound Lima bean pod were enabled to start the disease, which thereupon spread with great rapidity in the direction of the prevailing wind."

Precautions.—From what was last said, it is evident that some hints as to precautionary measures may be gained by a knowledge of the habits of the group to which the mildew of the Lima bean belongs. After a somewhat prolonged study of the relation obtaining between the weather and the development of fungi, it may be confidently asserted that there is no group that is more influenced by prevailing moisture than the downy mildews. The potato rot fungus (*Phytophthora infestans* D By.) is particularly fond of wet weather, with high temperature, and the records show that 1899, the year when the bean Phytophthora was discovered, was remarkable for its excessive summer and autumn rains. In the case of greenhouse lettuce it is found that sub-irrigation is almost a complete preventive of the mildew otherwise often quite destructive. It is safe to assume, therefore, that the amount of the bean mildew will depend quite

largely upon the amount of moisture, and in a dry season but little damage may be expected from it. But the rains cannot be controlled, and therefore the factor of precipitation remains an uncertainty. This much can become a practical matter, namely, the shunning of all lowlands that are apt to be wet. In other words, favor the higher and drier land for Lima beans, because in such situations the mildew will be less certain to gain a foothold.

Dr. Sturgis concludes his report of the remedies for the mildew as follows: "While from the nature of the disease it would seem probable that the use of fungicides would present many difficulties, yet from experiments in which Bordeaux mixture, ammonical copper carbonate solution, sulphur, and potassium sulphide were used it appeared that when three applications of Bordeaux mixture was followed by two applications of ammonical copper carbonate solution the amount of the disease was greatly reduced.

"The conclusions drawn from the experiments with fungicides show that even in a season most favorable for the Lima bean mildew, a thorough treatment of the vines with Bordeaux mixture will insure a crop. The selection of well-drained land and a light soil, reducing the number of vines in the hill, and planting the poles erect will insure conditions as little favorable to the development of the fungus as possible."

Mildew Late in the Season.

The late growth of bean mildew upon the Lima bean is remarkable in that it thrives upon the pods after the plants are killed by the frost. Upon October 24th, 1899, the writer could have picked from one large field bushels of pods in all stages of growth that were badly infested with the mildew and in a very flourishing condition. It is true, however, that while the foliage of the bean was destroyed by the frosts the pods remained apparently untouched, and therefore the tissue upon which the fungus grew was uninjured. The facts remain, nevertheless, that this Phytophthora grows luxuriantly in the cool weather of late autumn.

LIMA BEAN POD BLIGHT.

As early as the autumn of 1891, a damaging disease of pole Lima beans was met with. The following year it was found by Mr. J. B. Ellis, at Newfield, and described by him as *Phoma subcircinata* E. & E.* This disease produces large, brown patches with the dark spore spots arranged in concentric circles. In the worst cases the whole pod is involved, including the seeds, which fail to mature, and

* Proc. Acad. Nat. Sci., Philadelphia, Feb., 1893.

should they be used for planting would either fail to grow or produce sickly plants. While it has not been demonstrated, it is reasonable to suppose that, like the anthracnose, this disease can be carried over from season to season in infected seed, and therefore a safe precaution is to plant only the best of seed. Immature and diseased Lima beans can usually be distinguished by the lack of plumpness and bright color, and all such should be discarded at planting time.

Experiments only with this blight upon dwarf Limas have been carried out at the trial grounds, but from the good results there obtained it is to be expected that the pod blight upon pole Limas may be considerably checked by judicious spraying with the Bordeaux mixture or soda-Bordeaux.

The appearance of the pod blight is given in Plate III. (*a*), where the diseased areas are showing the pimples as small specks, in some instances in concentric rows. The same disease, as met with upon the foliage, is shown at *b* (Plate III.), where the leaflets are seen as ruined at the center, and show the spore spots as small dots similar to those upon the pods.

THE BEAN RUST.

The genuine rust (*Uromyces appendiculatus* (P.) Lev.) is one of the old fungous enemies of the bean, described by Persoon, in 1797 ; but it is a matter of congratulation that it is not usually a serious trouble in this country. This disease forms small brown circular spots that are scattered over the surface of the leaf, most abundantly upon the under side, while the leaf-stalks and even the pods are likewise affected. When upon the pods the spots are often larger and more elevated than upon the foliage, a difference that is due to the greater thickness and succulence of the attacked tissue. The color of the spots at first is nearly that of iron rust, from which fact the common name is derived, the appearance being due to the multitudes of minute spores that easily rub off, similarly with the rust of the wheat, oats and other grains in early summer. Later in the season the spore spots darken, because of the replacement of the orange-brown summer spores by those of a different shape and with a dark-brown color destined to remain as such until the next spring, when they germinate and inoculate the bean plants for another season.

Plate IV. (*A*) shows a portion of a leaf bearing the spore spots of the rust. Before the time for spore production the threads of the fungus have grown within the leaf and frequently the green color is replaced by a sickly yellow before the fungus has come to the sur-

face. It follows, therefore, that a large part of the destructive work of the rust is done before its presence is recognized and that but little hope remains of saving foliage that is already badly rusted. As with the rusts generally the effective treatment will consist in preventing the plants from becoming attacked. This may be done first of all by planting strong seed and growing the beans under the favoring conditions of a rich, congenial soil that has not become contaminated with the rust spores by the previous cropping with beans. The early spraying with fungicides will help to prevent the rust from getting a foothold upon the surface of the plants ; but when the rust appears in large amounts the crop of leaves and stems should be burned as soon as possible, and the growing beans upon that land omitted for a term of years.

As with other crops some sorts of beans are less susceptible to diseases than others, and therefore where practicable, the stronger should be grown to the exclusion of weaker varieties.

The bean rust is widespread and is not confined to the cultivated varieties. For example, Burrell* records it upon two species of wild beans, and Saccardo† mentions it upon eight species of true beans (Phaseolus) other than the ones under cultivation, and adds the species of the related genera Dolichos, Lablab, Vigna and Falcata as hosts. This adds to the difficulty in keeping the rust from the fields and gardens, for it may flourish upon wild plants that are possibly common weeds just beyond the cultivated land in pasture, forest or hedge row.

The Experiment Station literature is not extensive upon the subject. Professor Beach was one of the first to call attention to the bean rust‡ and present engravings of the disease upon leaf, stem and pods. Other Experiment Station botanists and horticulturists have mentioned the presence of the rust, so that it is safe to conclude that this disease is widespread, and while not particularly serious in the past, may at any time demand consideration, and therefore a knowledge of its appearance and habits is of value.

THE BEAN LEAF SPOT.

To a sixth disease of the bean, much more common than generally supposed, is to be charged much of the trouble ascribed to other fungi. This is the *Isariopsis griseola* Sacc., that for the lack of a

* Parasitic Fungi of Illinois, Part I., J. T. Burrell, 1895.

† Sylloge Fungorum, Vol. XII.

‡ Some Bean Diseases, Bull. N. Y. Agr. Exper. Sta., 48, 1892.

common name may be called the bean leaf spot. It is quite different from the other bean diseases, in being confined chiefly to the foliage, where it produces numerous spots, usually small and angular, without any colored border. The fungus itself forms a gray, mouldy covering upon the under surface of the spot where the spores are produced in vast numbers. The general appearance of this disease is shown at *B*, in Plate IV. From the superficial nature of the spore production, it is safe to conclude that this fungus is amenable to the ordinary treatment for similar diseases. The direct testing in this instance appears to be lacking.

THE BEAN LEAF BLOTCH.

The bean leaf blotch (*Cercospora cruenta* Sacc.) is not uncommon in the United States, but as it only affects the foliage the crop is shortened only indirectly. This disease produces patches of a brown color upon the leaves, causing them to become useless and fall away as in other kinds of cercosporas, like that of the violet leaf spot and the leaf spot of the celery. The spots of this Cercospora have an angular appearance, as with Isariopsis, from the fact that the small veins act as barriers to the fungus, as it spreads within the leaf, giving sometimes something of a checkerboard appearance to the surface of the affected leaf. This is not distinctly shown at *C*, Plate IV., because the disease is far advanced and many original patches have grown into one blotch. The last two kinds of leaf diseases here mentioned are easily distinguished, as the engravings clearly show.

The Cercospora belongs to a group of fungi that is not difficult to check with fungicides, as repeated tests have shown with a common species upon the beet, and therefore the treatment which should be given for anthracnose or rust will meet the demands of the leaf blotch.

SUMMARY.

Seven fungous diseases of beans have received consideration in the preceding pages, namely :

1. The anthracnose or pod spot (*Colletotrichum lagenarium* (Pers).)
2. The bean bacteriosis (*Pseudomonas phaseoli* Sm.)
3. The Lima bean mildew (*Phytophthora phaseoli* Thax.)
4. The Lima bean pod blight (*Phoma subcircinata* E. & E.)
5. The bean rust (*Uromyces appendiculatus* (Pers).)
6. The bean leaf spot (*Isariopsis griseola* Sacc.)
7. The bean leaf blotch (*Cercospora cruenta* Sacc.)

All of these were met with in the field studies of the diseases, but the first three, being the most common and serious enemies, have been the subjects for special treatment.

The bean seed is often infested with the anthracnose, and becomes thereby a prominent, if not the chief, means of tiding over the inactive or winter season. The same is doubtless true with bacteriosis.

It has been shown that soaking the seed in fungicides, while destructive to the fungus, is not always without ill effect upon the seed itself. Experiments differ upon this point and further investigations are here needed.

There is only one opinion as to the desirability of discarding all diseased seed before planting and using only that which is mature and healthy. This is not only recommended but strongly urged.

It has been demonstrated through seven consecutive years of beans upon the same land, two crops each season, that the anthracnose is checked by fungicides. The same is true of the bacteriosis. The Bordeaux mixture has proved of substantial value as a remedy for bean mildew.

While the experimental sprayings have been at intervals of ten days, it is not recommended that they be more than three in number for the ordinary wax sorts. For pole varieties, or any that require the whole season, sprayings once in three weeks would perhaps be most profitable, and yet the distribution of the drenching rains should determine the times of the applications.

It was shown that old spotted pods, when used as a mulch, greatly increased the disease upon the area thus covered. All such refuse, whether of pods or stems and leaves, should be burned.

A rotation of crops is desirable from the standpoint of freedom from disease, but it has been demonstrated that with frequent spraying beans may be grown with profit indefinitely upon the same land.

The leading points in bean growing are—(1), to have strong healthy seed of the least susceptible sorts; (2), planted not too close or deep; (3), in rich, well-drained soil, and (4), spray with Bordeaux or its equal soda-Bordeaux at three-week intervals. To this is added the not less important point of burning all the refuse of the field as soon as possible after the crop is harvested.